## REMARKS

The specification has been amended and new Fig. 7 has been added. Claims 15-28 are pending. Claims 15, 23, 24 and 26-28 have been amended. No new matter has been added. In view of the above amendments and the following remarks, it is respectfully submitted that all of the pending claims are allowable.

The Examiner objected to the specification stating that the "Fig. 1" in paragraph [0004] should be changed to "Fig. 2". However, in paragraph [0004], the Applicants are describing the prior art form of a DC saturated HTS FCL which is shown in Fig. 1. Fig. 2, in contrast, shows an exemplary embodiment of the present invention. Thus, it is respectfully submitted that the reference to Fig. 1 is correct as written and that the Examiner should withdraw this objection.

The Examiner further objected to the specification and the drawings for failing to provide support and an enabling written description for the subject matter of claim 28. In view of the addition of new Fig. 7 and the amendments to paragraph [0046] above, it is respectfully requested that the Examiner withdraw the objections to the specification and drawings with regard to claim 28.

Claims 15-17 stand rejected under 35 U.S.C. § 102(b) as anticipated by U.S. Patent No. 5,930,095 to Joo et al. ("Joo").

Claim 15 recites a superconducting current limiting device for current limiting a circuit, comprising "an interconnected high magnetic permeability structure including a central core coupled to at least a first arm and a second arm branching off there from" and "*a high temperature superconductor superconductive coil surrounding the central core for biasing the central core into magnetic saturation during normal operation*" in combination with "a first alternating current coil surrounding the first arm and coupled to an alternating current source" and "a second alternating current coil surrounding the second arm and coupled to an alternating

current load, wherein the first and second alternating current coils are magnetically coupled to the central core, *the device limiting the current passing through the device upon an occurrence of a fault condition in the load by taking the central core out of the magnetic saturation during the fault condition, thereby providing an impedance between the current source and the current load.*"

Initially, it is noted that Joo describes a shielded core fault current limiter (SCFCL) which is different from the superconducting current limiting device recited in claim 15 which would be categorized by one of skill in the art as a saturable magnetic core fault current limiter (SMCFCL). That is, as recited in claim 15, the superconducting current limiting device is initially in saturation and is taken out of saturation upon an occurrence of a fault condition.

Furthermore, the mode of operation of the SCFCL described in Joo is where the fault current changes the magnetic flux in the iron core, which in turn, changes the state of the superconductor, which is sensed and used to switch the fault current. The superconducting coils only react to changes in the flux of the magnetic core. Specifically, variations in the flux flow through the magnetic coils induce currents in the superconducting rings that are placed around the limbs. In contrast, according to the present invention, an energizing current is input to the superconducting coil such that the magnetization of the iron core is forced into an initial state of full saturation. When a fault current occurs, the current in the superconducting coils does not change, and the fault current changes the magnetization state of the iron core, which naturally provides an impedance to the current flow in the AC (load) coil, as this brings the magnetization of the iron core below the knee point on the magnetization (B-H) curve.

Additionally, in the SCFCL of Joo, the superconducting coil is designed to quench (i.e., destroy the superconductivity) during operation, which can be problematic with regard to the supporting cryogenic systems and the resistive load on the system. The quench may also be deleterious for long-term stability of the superconductor, imposing a limitation on its use, and providing a potential failure mechanism of the device. It also limits the reaction and reset times

of the device, and therefore, makes it undesirable for critical applications. According to the present invention, on the other hand, the superconductor does not quench, and is energized with a static DC current during all modes of operation, ensuring that any fault current encountered is sufficiently limited. The present invention also enables a quick fully automatic reset of the device after a fault, and provides a fail safe operation.

Therefore, it is respectfully submitted that claim 15 is allowable over Joo. Because claims 16 and 17 depend from, and, therefore include all of the limitations of claim 15, it is respectfully submitted that these claims are also allowable.

Claims 15-21 and 23 stand rejected under 35 U.S.C. § 102(b) as anticipated by U.S. Patent No. 4,045,823 to Parton et al. ("Parton '823").

The device described in Parton '823 suffers from a number of problems, including excessive size and bulk and relies on using Low Temperature Superconductor (LTS) as the energizing coil, requiring excessive cooling. The Parton '823 device could also be proposed using a copper racetrack coil instead of LTS, but the sheer increase in size this would invoke, and the electrical loses imposed in using a copper conductor in permanently energizing the copper DC coil would make it utterly impractical and commercially worthless. The photograph submitted herewith as Exhibit A illustrates the excessive bulk of just the racetrack coil needed to implement the Parton '823 device.

Furthermore, the article submitted herewith as Exhibit B entitled, "Fault Current Limiter with Superconducting DC Bias" by Raju et al., IEE Proc, Vol. 129, July 1982, discusses the actual implementation of the Parton '823 device, and further illustrates in its figures the excessive bulk of the Parton '823 device. In the actual implementation of the Parton '823 device, as discussed by the Raju et al. article, it was further necessary to implement a screen around the DC bias core in order for proper operation of the device. Raju et al. states, "[t]he superconducting winding is surrounded by an electromagnetic screen to protect it from

alternating magnetic fields which appear during alternate desaturation of the cores." Raju et al., p. 166, col. 2. This appears to have become the subject of U.S. Patent No. 4,117,524 to Parton et al. (see col. 1, lines 36-60).

The present invention does not suffer from any of the problems associated with the Parton device. As noted in the discussion on distortion in the Parton '823 device on Page 169 by Raju et al., a distortion of the waveform on limiting a fault will occur unless the electromagnet circuit is absolutely balanced and symmetrical. This is very difficult to achieve with a three-phase system set out as disclosed in the Parton '823 device, as all six cores independently contribute to the net electromagnetic balance of the device, causing an unstable complex response that is difficult to balance using a single large racetrack loop surrounding six independent cores. Driving one of the iron cores in the Parson '823 device out of saturation, as is required by the theory of operation, knocked the entire system out of "magnetic equilibrium," producing distorted waveforms and harmonics. The Parton '823 device uses LTS and, thus, generates excessive harmonics that were not able to be mitigated by engineering. This can be seen from the structure of the plotted waveforms in Figs. 12 and 13 of Raju et al. These excessive harmonics lead to deleterious operation of the FCL and were one of the reasons for its commercial unacceptability.

The bringing together of the cores and the use of an HTS solenoid in the present invention produced unexpected results in the elimination of distorted waveforms and did not generate harmonics under fault conditions. HTS wires in the central solenoid coil were found to have different electromagnetic response characteristics to LTS wires, and they are not affected in the same way as LTS wires or as copper wires are. This means that the spacings and clearances in the cryostat can be made much smaller in the present invention, which is vital for commercial implementation. Further analysis of these unexpected advantages was subsequently undertaken by the inventors, and was published in the paper attached hereto as Exhibit C entitled, "Performance of a 1 MVA high temperature superconductor-enabled saturable magnetic core-type fault current limiter" by Hawley et al, published in Superconductor Science and Technology, 18, (2005) 255-259. As can be seen from examination of Figs. 5 and 6 of this

paper, there was a divergence between the modeled (expected) FCL fault current and the measured (actual) FCL fault current produced by an actual device, *with the measured FCL fault current having effectively zero harmonic output, compared with the 3rd, 5th, 7th, 11th, and 13th order harmonics predicted by the theoretical FCL device using theory developed in the Parson '823 device*. This negation of any operational harmonics means that an improved FCL device was created, and the lack of harmonics is a vital necessity for commercial application.

It is thought that the harmonics are reduced for a number of reasons:

(1) As stated, HTS conductors appear to exhibit a different electromagnetic response to changes in an external field compared to either LTS or copper conductors, making such transitions less sharp and inherently more stable. This results in a cleaner and smoother waveform,

(2) The central bias core concept has a strong degree of magnetic coupling between the iron yokes and the central solenoid, which effectively means that they act as a single core, even thought they are independent, and so the magnetic equilibrium of the magnetic circuit is not distorted as in the case of six separate cores,

(3) The magnetic response of the two machines is different under fault conditions, as the central biased core has a more homogeneous response. This means that clipped square waves are not produced in this invention, because of the reasons described above, i.e. the homogeneous magnetic properties of the yokes and iron laminations and the electromagnetic symmetry of the HTS central coil combine to produce symmetrical rounded-top clipped waves that produce no spectral distortion or harmonics.

The arrangement of the Parton '823 device does not include a central core connected to a first and second arm, but rather, each arm of Parton '823 is distinct. The utilization of a central core is also thought to eliminate any harmonics in the operational device that is the subject of this invention, through a complex magnetic interaction that takes place during tracking of the B-H response on registering a fault. This linear response from the combination of the six cores magnetized in a symmetrical orientation does not occur in the Parson '823 device.

Additionally, the preferred embodiments of the present invention improves on existing SMCFCL designs by providing a means of constructing a practical three-phase FCL with a single DC biasing coil, and also provides a means by which the amount of current limited can be adjusted. Furthermore, the preferred embodiments of the present invention also provide a means of providing a fault current limiter that can limit both line faults and also line-to-ground faults as well.

Therefore, it is respectfully submitted that claim 15 is allowable over Parton '823. Because claims 16-21 and 23 depend from, and, therefore include all of the limitations of claim 15, it is respectfully submitted that these claims are also allowable.

Claims 24 and 25 stand rejected under 35 U.S.C. § 102(b) as anticipated by U.S. Patent No. 4,336,561 to Murphy.

Claim 24 recites a multistage superconducting fault current limiter device comprising "a first superconducting fault current limiter limiting a current during a first portion of a transient fault" in combination with "a second superconducting fault current limiter limiting the current during a second portion of the transient fault" wherein each of the first and second superconducting fault current limiters includes "an interconnected high magnetic permeability structure including a central core coupled to at least a first arm and a second arm branching off there from" and "*a high temperature superconductor superconductive coil surrounding the central core for biasing the central core into magnetic saturation during normal operation*" in combination with "a first alternating current coil surrounding the first arm and coupled to an alternating current source" and "a second alternating current coil surrounding the second arm and coupled to an alternating current load, wherein the first and second alternating current coils are magnetically coupled to the central core, *the device limiting the current passing through the device upon an occurrence of a fault condition in the load by taking the central core out of the magnetic saturation during the fault condition, thereby providing an impedance between the current source and the current load.*"

In contrast, Murphy describes a superconducting transformer with windings arranged so that the transformer exhibits a lower input impedance under steady state conditions and a higher input impedance under fault or overload conditions. The primary and secondary windings are divided into main and auxiliary stacked layers arranged to provide a high leakage reactance and thereby limit the transient or overload current flow which is automatically switched or shunted into the auxiliary windings during fault operation. It is respectfully submitted that Murphy neither discloses nor suggests that the windings of the superconducting transformer "bias the central core into magnetic saturation" or limit "the current passing through the device upon an occurrence of a fault condition in the load by taking the central core out of the magnetic saturation during the fault condition, thereby providing an impedance between the current source and the current load," as recited in claim 24.

Therefore, it is respectfully submitted that Murphy neither discloses nor suggests first and second superconducting fault current limiters which include the elements recited in claim 24. Because claim 24 depends from, and, therefore includes all of the limitations of claim 25, it is respectfully submitted that this claim is also allowable.

Claims 26 and 27 stand rejected under 35 U.S.C. § 102(b) as anticipated by U.S. Patent No. 4,117,524 to Parton et al. ("Parton '524).

Claim 26 recites a multiphase superconducting current limiter device comprising "a single cryostat" and "a single cryocooler" in combination with "an interconnected high magnetic permeability structure including a central core coupled to at least a first arm and a second arm branching off there from" and "*a single superconducting coil surrounding the central core for biasing the central core into magnetic saturation during normal operation*" and "a first alternating current coil surrounding the first arm and coupled to an alternating current source" in combination with "a second alternating current coil surrounding the second arm and coupled to an alternating current load, wherein the first and second alternating current coils are magnetically coupled to the central core, *the device limiting the current passing through the device upon an*

*occurrence of a fault condition in the load by taking the central core out of the magnetic saturation during the fault condition, thereby providing an impedance between the current source and the current load.*"

As mentioned above, the Parton '524 device "concerns improvements in the current-limiting device of the aforesaid application Ser. No. 648,980" which is the subject matter of Parton '823. The Parton '524 device simply includes a flux screen of electrically-conductive material surrounding the superconducting winding to screen it against alternating magnetic flux. Thus, it is respectfully submitted that Parton '524 neither discloses nor suggests "a single superconducting coil surrounding the central core for biasing the central core into magnetic saturation during normal operation" and "the device limiting the current passing through the device upon an occurrence of a fault condition in the load by taking the central core out of the magnetic saturation during the fault condition, thereby providing an impedance between the current source and the current load," as recited in claim 26. Thus, for these reasons and the reasons stated above with reference to claim 15, it is respectfully submitted that claim 26 is allowable.

Claim 27 recites a DC saturated superconducting current limiter device including limitations substantially similar to claim 26 such as "a *high temperature superconductor superconductive coil surrounding the central core for biasing the central core into magnetic saturation during normal operation*" and "*the device limiting the current passing through the device upon an occurrence of a fault condition in the load by taking the central core out of the magnetic saturation during the fault condition, thereby providing an impedance between the current source and the current load.*"

Therefore, for the reasons stated above with reference to claims 26 and 25, it is respectfully submitted that claim 27 is also allowable. Claim 27 further recites "an interconnected high magnetic permeability structure including an iron core including at least one air gap." It is respectfully submitted that Parton '524 disclose no such air gap in an iron core

and, as such, is allowable.

Claims 15 and 16 stand rejected under 35 U.S.C. § 103(a) as unpatentable over PCT/DE01/02550 to Neumuller et al. ("Neumuller") in view of Joo. The language of the rejection references the English language equivalent of Neumuller as provided in U.S. Patent No. 6,795,282.

In contrast to claim 15, Neumuller describes a superconducting device including at least one inductive current limiter unit which contains at least one conductor track which carries a switching current in a limiting situation, at least one annular body which is inductively associated with the conductor track and is composed of high-$T_c$ superconductor material, and a core limb which is surrounded by the annular body and is composed of soft-magnetic material. It is respectfully submitted that Neumuller neither discloses nor suggests "*a high temperature superconductor superconductive coil surrounding the central core for biasing the central core into magnetic saturation during normal operation*" and "*limiting the current passing through the device upon an occurrence of a fault condition in the load by taking the central core out of the magnetic saturation during the fault condition, thereby providing an impedance between the current source and the current load*," as recited in claim 15. As discussed above with reference to claim 15, Joo neither discloses nor suggests these limitations and, as such, does not cure the deficiencies of Neumuller.

Therefore, it is respectfully submitted that claim 15 is allowable. Because claim 16 depends from, and, therefore includes all of the limitations of claim 15, it is respectfully submitted that these claims are also allowable.

Claim 17 stands rejected under 35 U.S.C. § 103(a) as unpatentable over Neumuller in view of Joo in further view of U.S. Patent No. 5,115,676 to Spreen. Claims 19, 21 and 22 stand rejected under 35 U.S.C. § 103(a) as unpatentable over Parton '823 in view of "Transformers - The Basics Section 1" (Elliott).

It is respectfully submitted that neither Spreen nor Elliott cure the above-described deficiencies of Neumuller, Joo and Parton '823 described above with reference to claim 15. Thus, it is respectfully submitted that because claims 17, 19, 21 and 22 depend from, and, therefore include all of the limitations of claim 15, these claims are also allowable.

Claim 28 stands rejected under 35 U.S.C. § 103(a) as unpatentable over Parton '823 in view of Spreen.

Claim 28 recites a series of multi-phase DC saturated superconducting current limiter devices comprising "a plurality of iron cores, wherein at least one of the plurality of iron cores includes at least one air gap, wherein at least one of plurality of iron cores includes a continuous iron core," wherein each of the devices includes "*a high temperature superconductor superconductive coil surrounding the respective iron core for biasing the iron core into magnetic saturation during normal operation*" in combination with "a first alternating current coil surrounding a first arm coupled to the respective iron core and coupled to an alternating current source" and "a second alternating current coil surrounding a second arm coupled to the respective iron core and coupled to an alternating current load, wherein the first and second alternating current coils are magnetically coupled to the respective iron core, *the device limiting the current passing through the device upon an occurrence of a fault condition in the load by taking the respective iron core out of the magnetic saturation during the fault condition, thereby providing an impedance between the current source and the current load.*"

Claim 28 recites limitations substantially similar to claim 15, and it is respectfully submitted that Spreen does not cure the above-described deficiencies of Joo with reference to claim 15. Spreen teaches a sensor for measuring fluid pressure in a system (i.e., a fluid flowing through a principal conduit or at a certain point of a pressure vessel). The sensor consists of a sensor head that edge mounts a first, isolating diaphragm mechanically coupled to a second, sensor diaphragm by a drive rod. Thus, it is respectfully submitted that Spreen neither discloses nor suggests "a high temperature superconductor superconductive coil surrounding the respective

iron core for biasing the iron core into magnetic saturation during normal operation" and "limiting the current passing through the device upon an occurrence of a fault condition in the load by taking the respective iron core out of the magnetic saturation during the fault condition, thereby providing an impedance between the current source and the current load," as recited in claim 28.

Therefore, it is respectfully submitted that neither Joo nor Spreen, either alone or in combination, discloses or suggests the elements of claim 28.

## CONCLUSION

In light of the foregoing, the Applicants respectfully submit that all of the now pending claims are in condition for allowance. All issues raised by the Examiner having been addressed, an early and favorable action on the merits is earnestly solicited.

Respectfully submitted,

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